Possible solutions for a transport system compliant with the energy supply and the environment: measurable analyses

URBAN MOBILITY INDIA 2011

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European Business and Technology Centre

POSSIBLE SOLUTIONS FOR A TRANSPORT SYSTEM COMPLIANT WITH THE ENERGY SUPPLY AND THE ENVIRONMENT: MEASURABLE ANALYSES

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Session «Integrated approach to transport planning»

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1. Aims of society (India, EU) related to transport systems and energy

   ➡ GENERAL TRANSPORT PLANNING

2. Measurable evaluations, well-to-wheel analysis

   ➡ MEASURABLE ANALYSES

3. EU directives, action plans on the promotion of clean and energy-efficient transport systems

   ➡ REGULATIONS

☞ CONCLUSIONS

Some European cities, 1900

Same cities, today

London ....

Milan

Paris

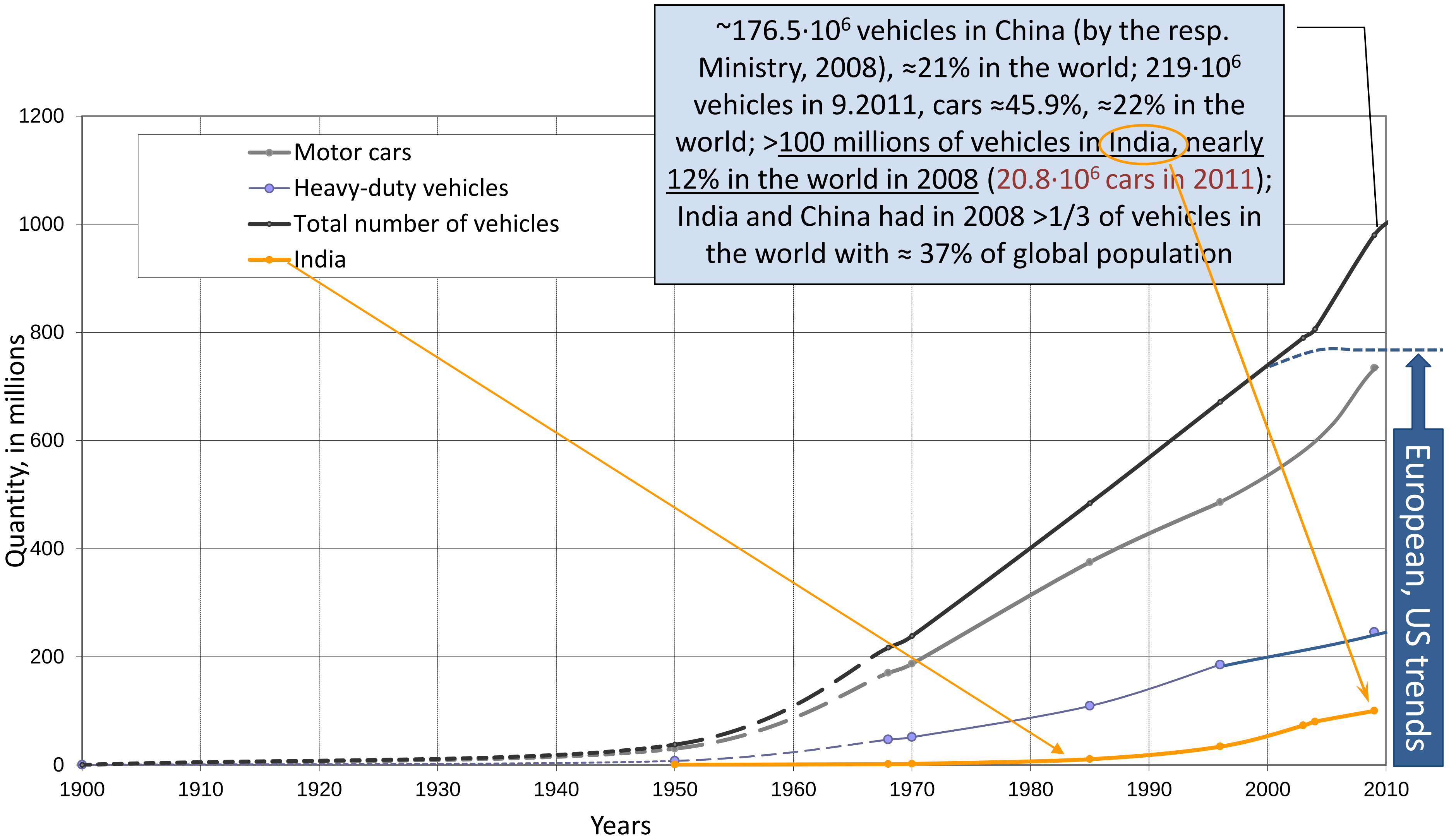
A REACHED **AIM** OF THE EUROPEAN SOCIETY

DIFFUSED **MOTORISATION**

Nowadays frequently REGULATED, CONTROLLED

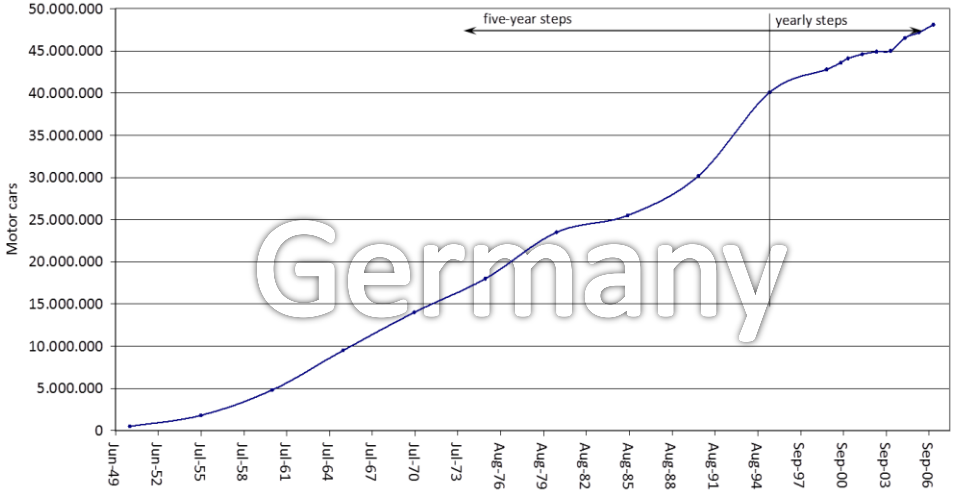
Vehicles circulating in the WORLD

approximate trend on the basis of few known data and estimates from different sources

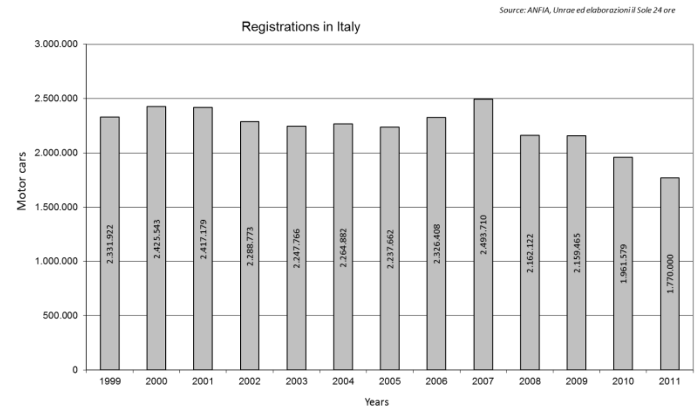


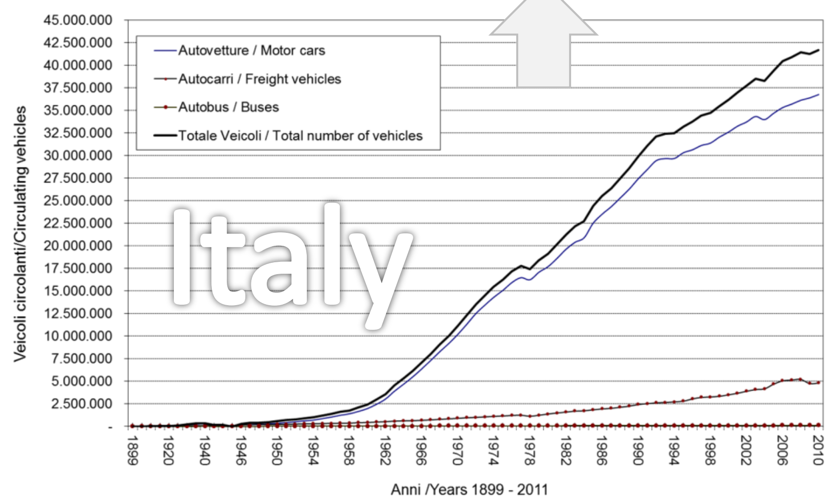
Fonti /Sources: varie/ous, Databook Energia e Petrolio 2009, The Physics Factbook, World motor vehicle market

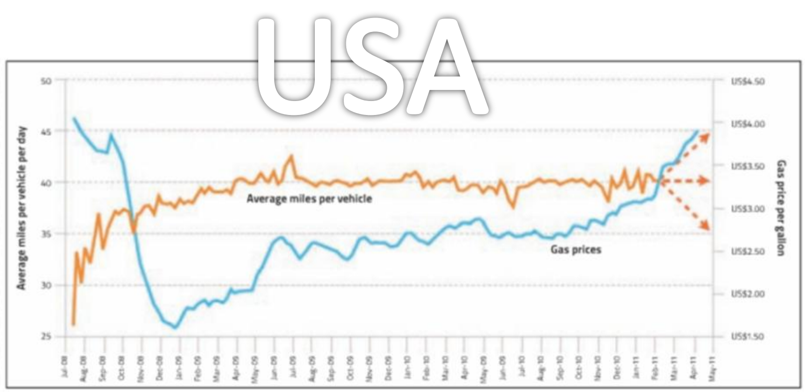
Examples: circulating vehicles (D, I), registrations (I), daily travels (US): *features of a saturated market.*



Federal Motor Transport Authority (KBA) 2008; Transportation (2009, 36)







Source: USDOT, Federal Highway Administration: Progressive

USA [Dept. of Transport, 2011] average miles/vehicle per day, 2008-2011

The development of the

circulating vehicles, **infrastructures** and **personal mobility**,

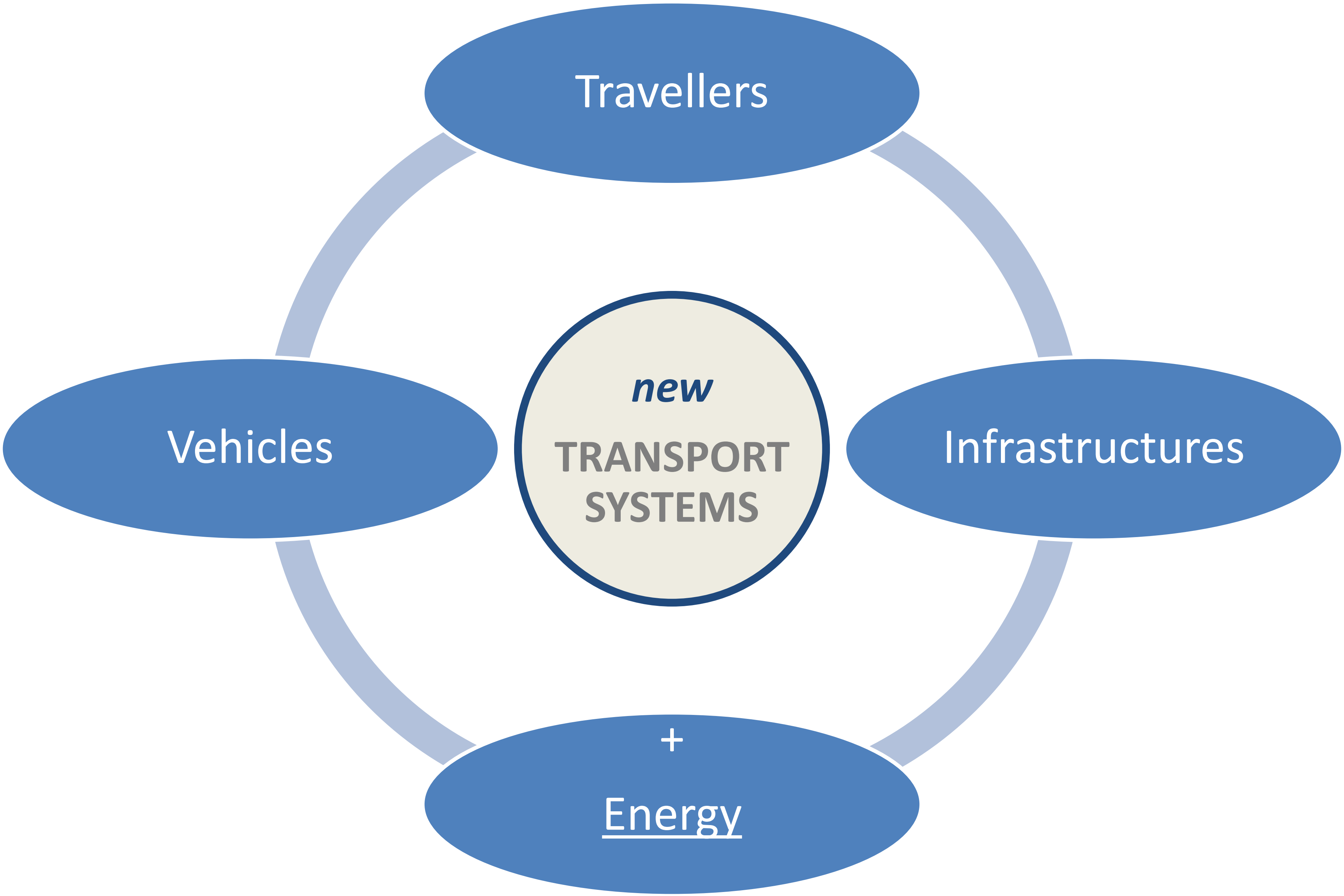
which have significantly marked the

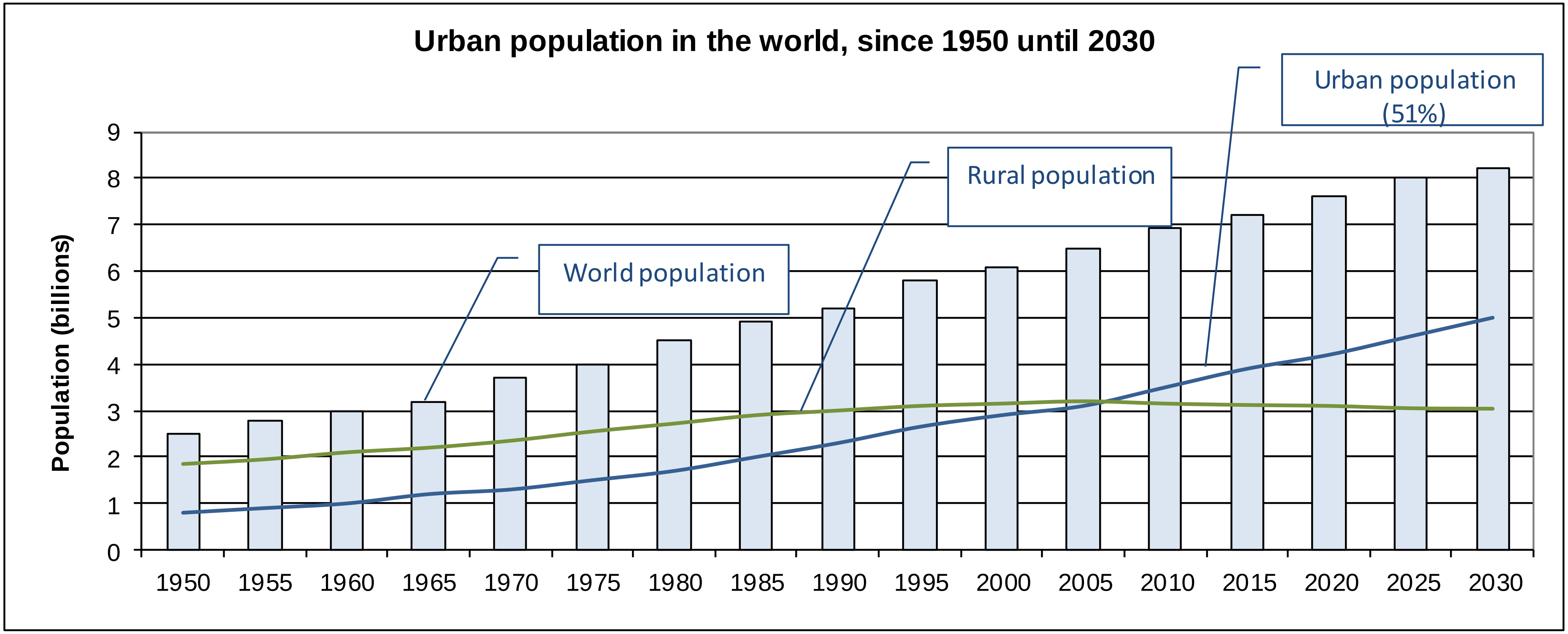
second half of the last century in Europe,

show today some conditioning factors.

A. saturation of the land
B. limitedness of the energy resource
C. respect of the environment
D. maintenance of all the existing infrastructures
E. safety increase in transport systems, a will
F. relationships among people and families.

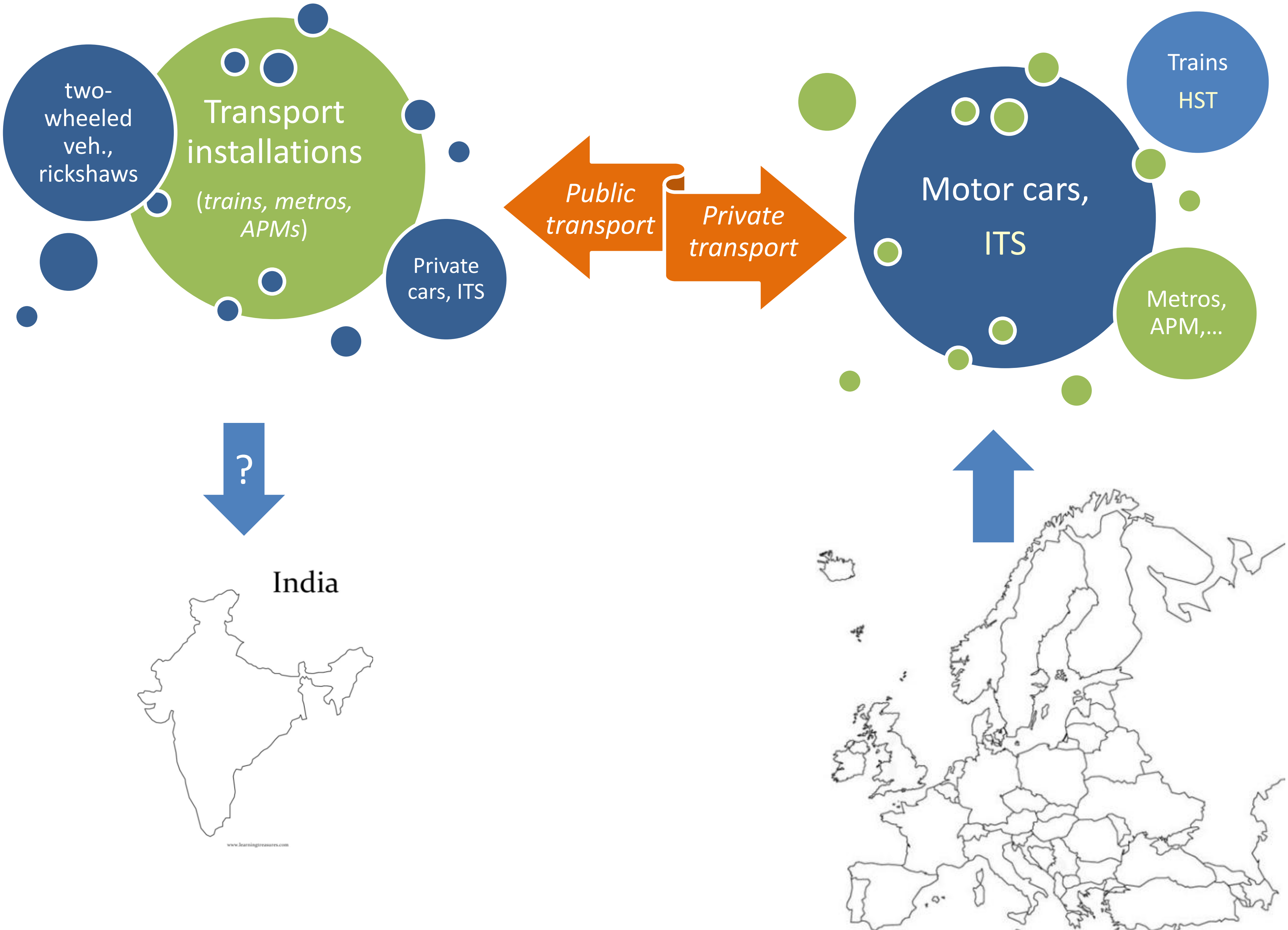
India?


Travellers
Vehicles
new
TRANSPORT SYSTEMS
Infrastructures
+
Energy



The **urban population** of the **EU-27** amounted to
73% of the total population in 2008

[Source: EU energy and transport in figures, Statistical Pocketbook 2010, p. 18]


two-wheeled veh., rickshaws
Transport installations
(trains, metros, APMs)
Private cars, ITS
Public transport
Private transport
Motor cars, ITS
Trains
HST
Metros, APM,…
?
India

Bicycles, motorcycles, rickshaws and public transport (subways)?

A private motorised mobility? 2-3, 4 wheels?

A balanced scenario? With “ITS” (intelligent transport systems)?

On which basis?

Fixed installations

Emissions *in operation*

Government presence

Bids and tenders

Integrated planning and managed mobility

India (2008),CO_2 Transport systems: ≈9,2%

Figure 1. CO_2 emissions by fuel

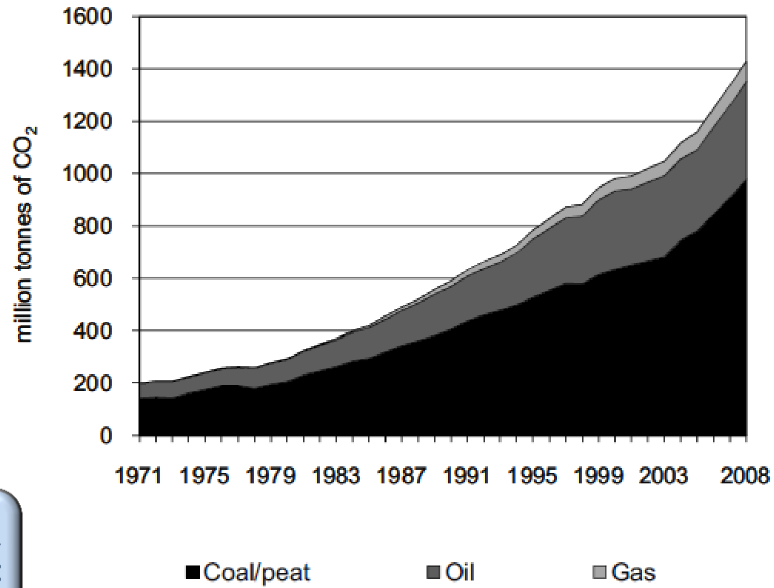


Figure 2. CO_2 emissions by sector

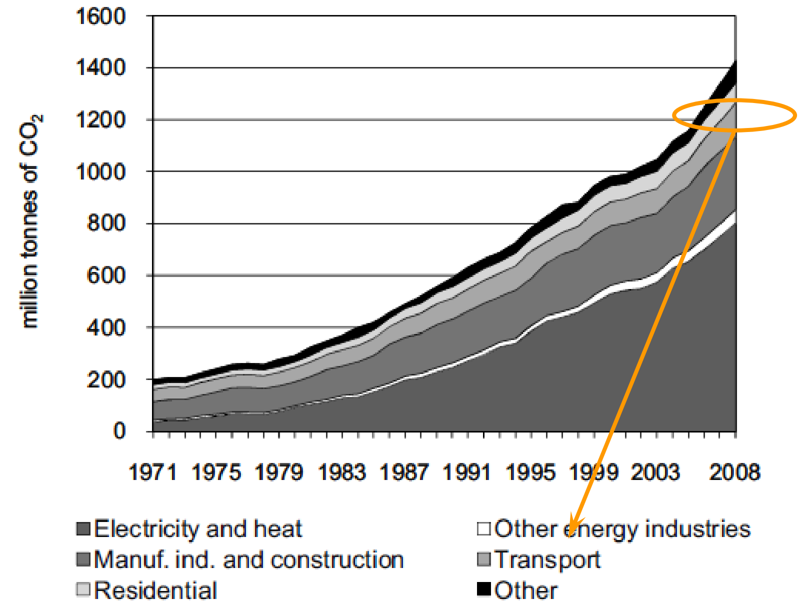


Figure 3. CO_2 emissions by sector

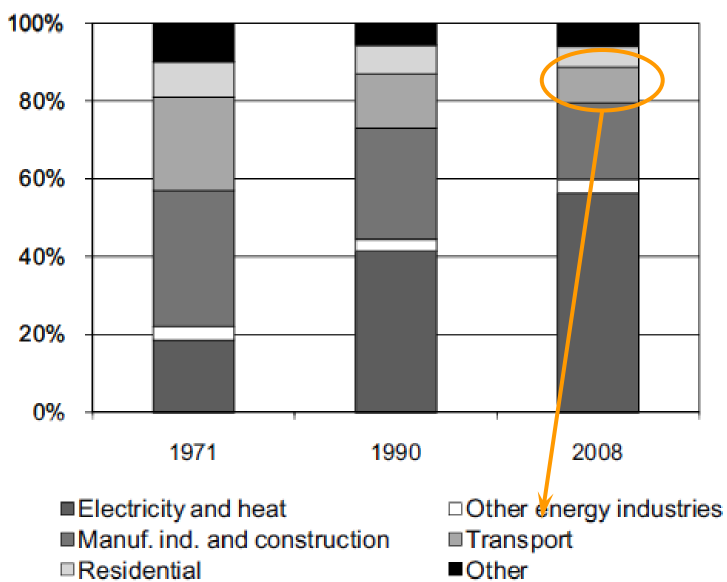
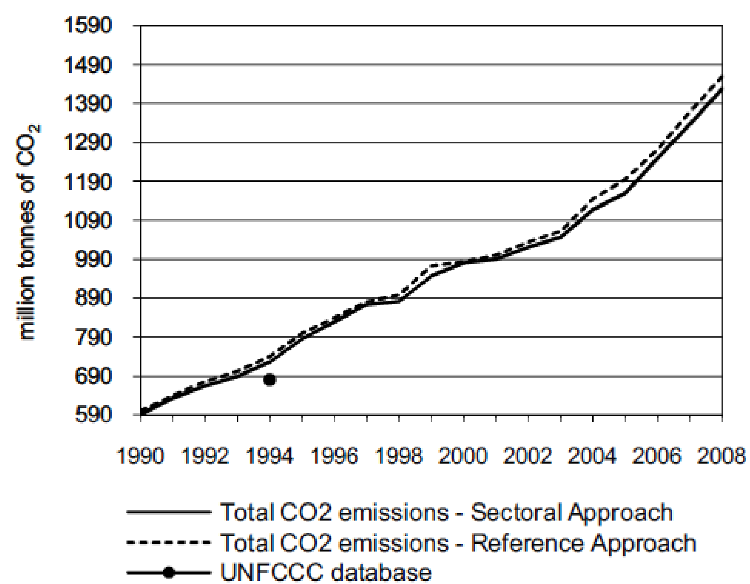
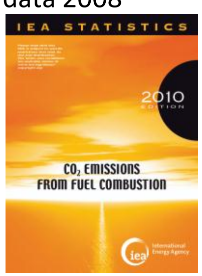
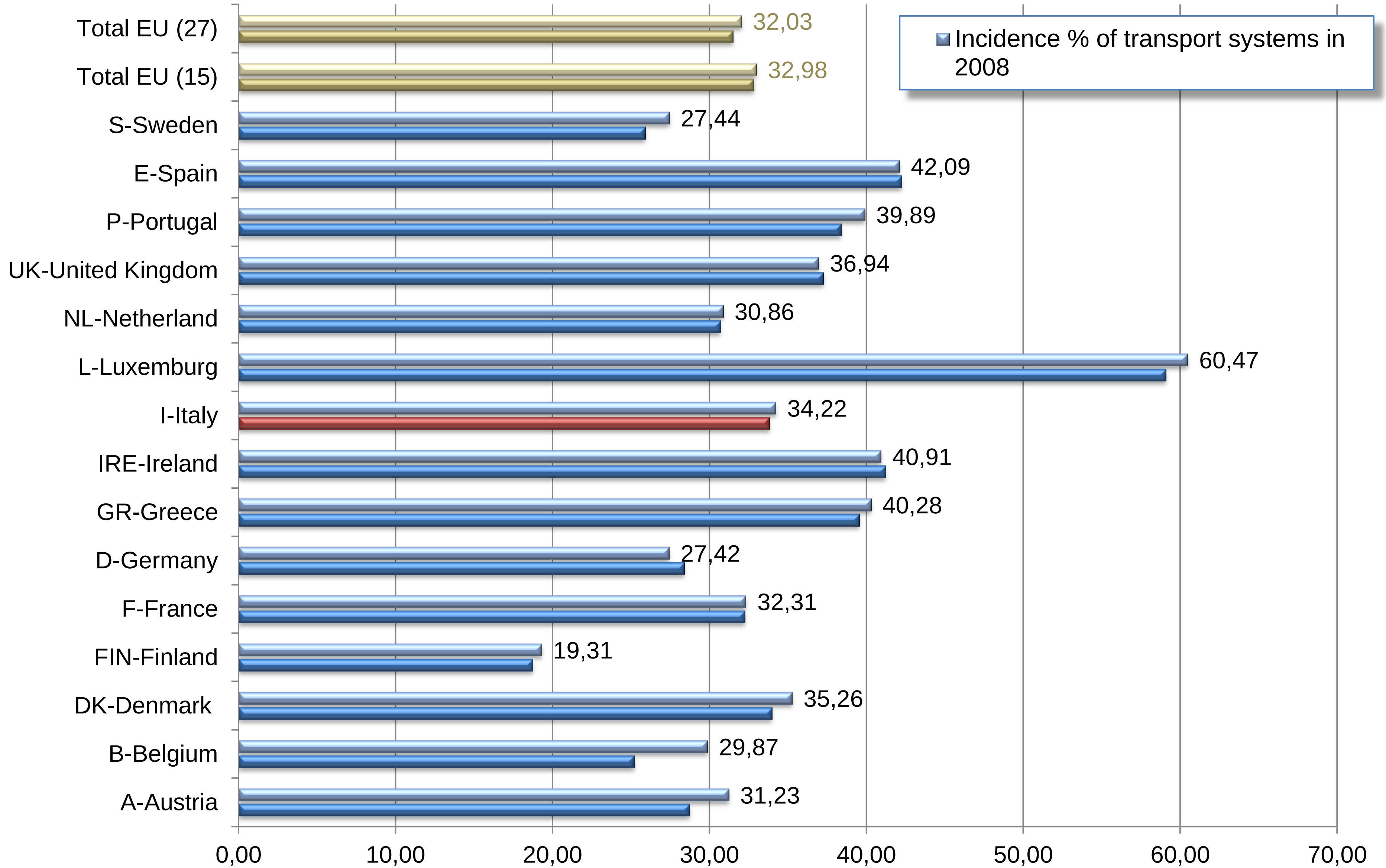


Figure 4. Reference vs Sectoral Approach



Source: IEA, 2010 data 2008





EU (2008), Transport systems: CO_2 at 24%, energy use ≈32-33%

Sources: Eurostat and Databook, “Energia e Petrolio in Italia” 2009, 2011 by “Unione Petrolifera” - I

Private cars

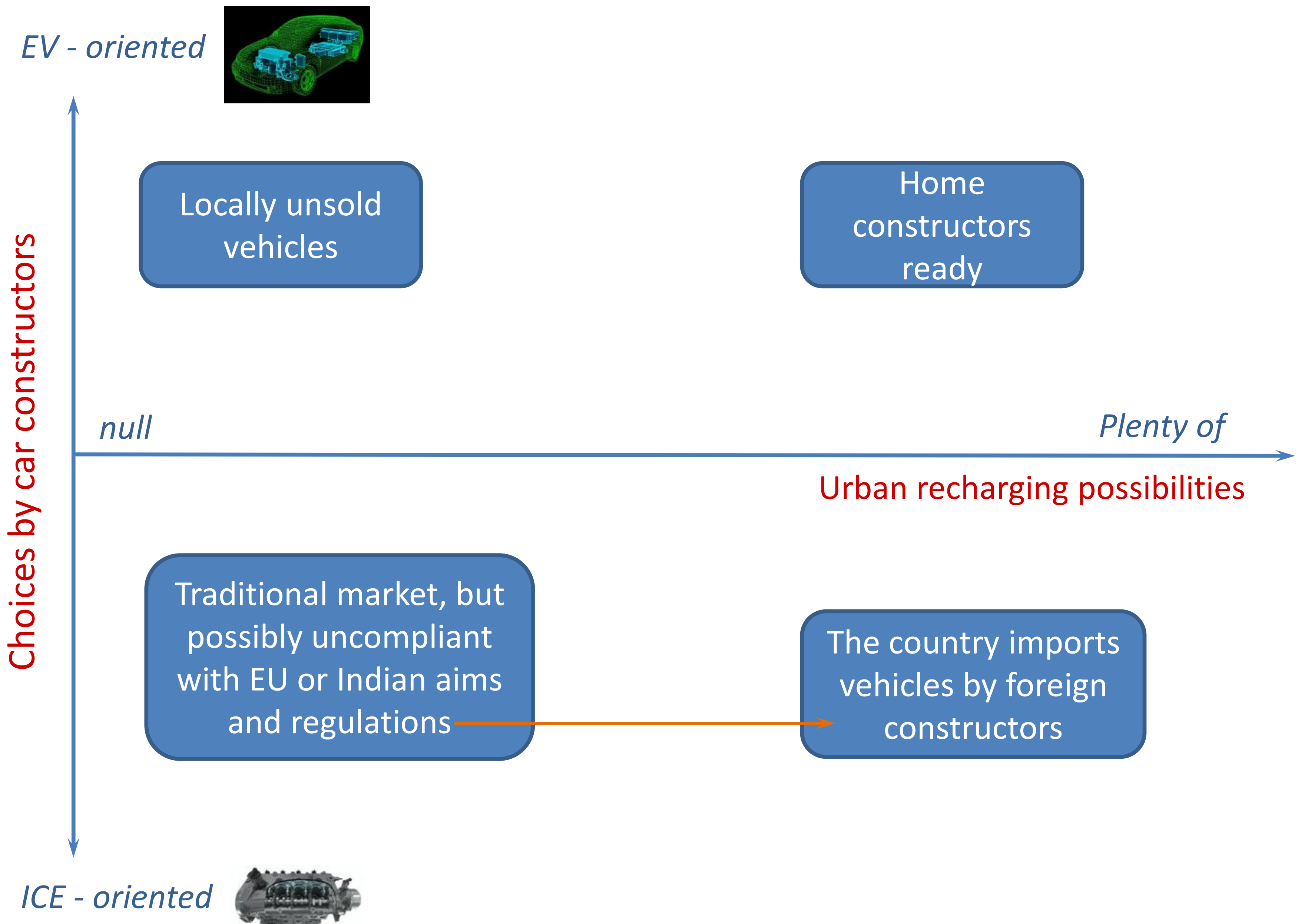
Emissions

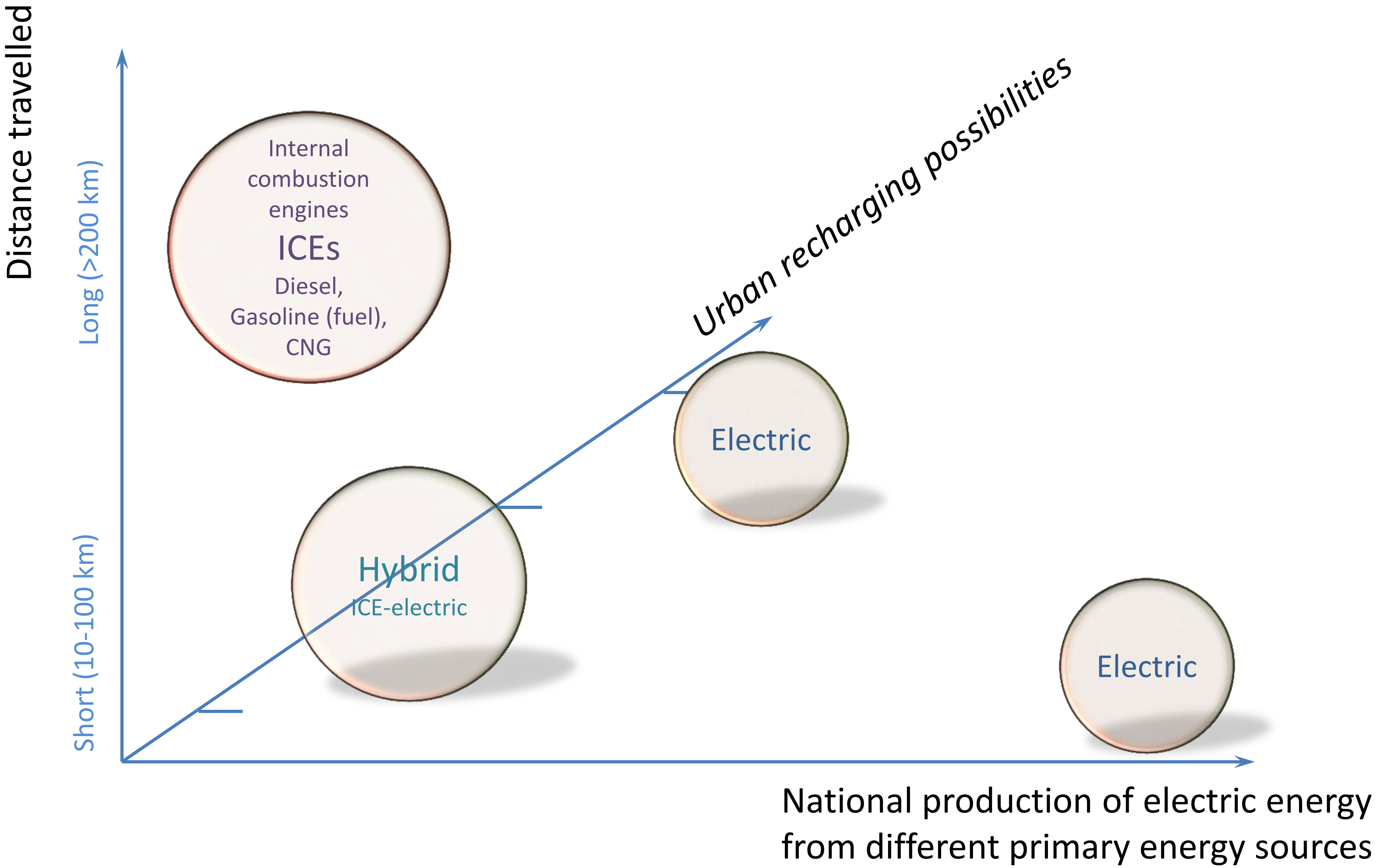
Unless new engines, hybrid vehicles, electric vehicles (EV) are pursued

City towns: energy solutions

Recharge areas

Private mobility, with more «ITS»


EV - oriented
Locally unsold vehicles
Home constructors ready
Choices by car constructors
null
Plenty of
Urban recharging possibilities
Traditional market, but possibly uncompliant with EU or Indian aims and regulations
The country imports vehicles by foreign constructors
ICE - oriented

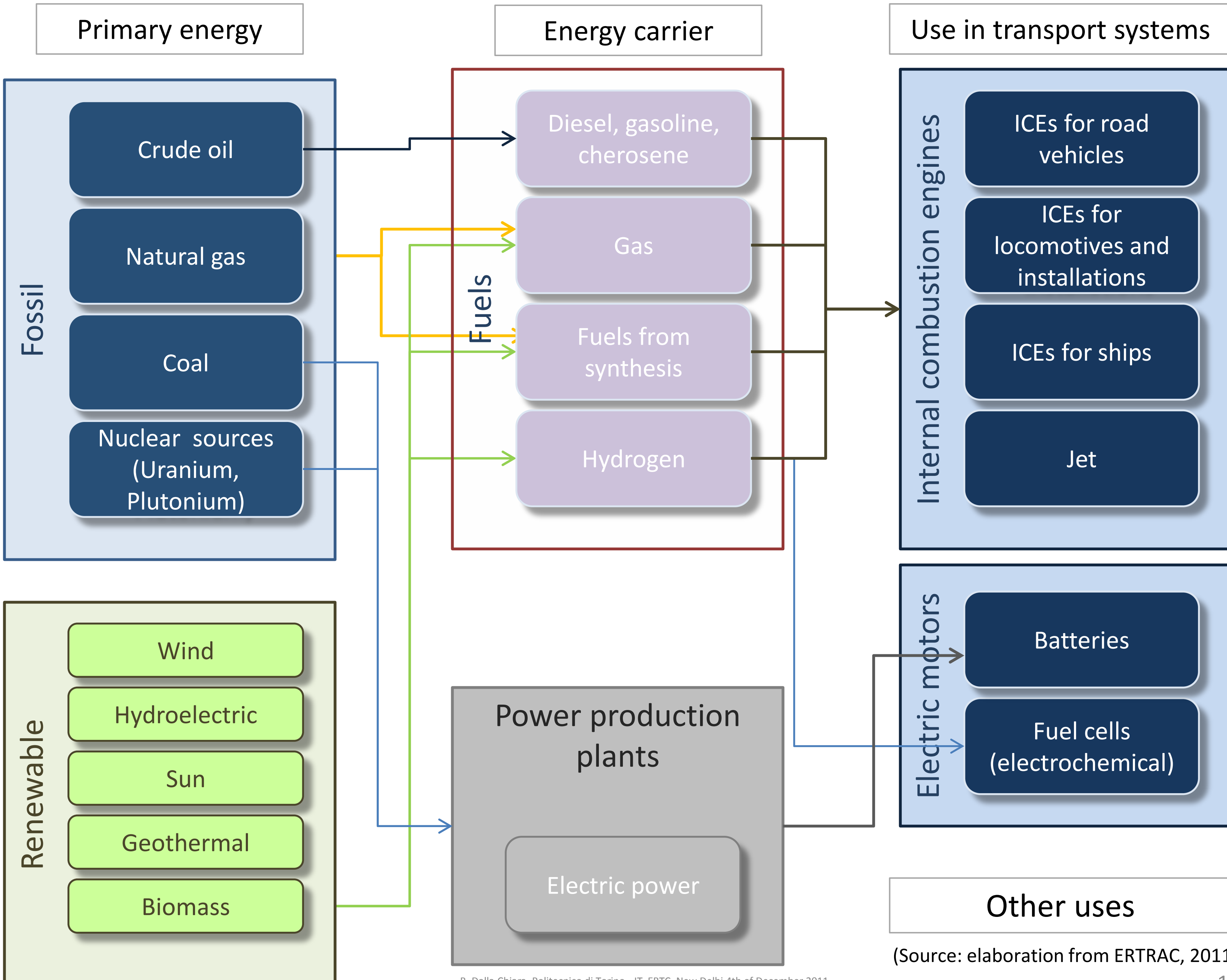


Point of view of the traveller or driver

POSSIBLE SOLUTIONS FOR A TRANSPORT SYSTEM COMPLIANT WITH THE ENERGY SUPPLY AND THE ENVIRONMENT:

MEASURABLE ANALYSES

On which basis we may prepare a high-level integrated planning?



(Source: elaboration from ERTRAC, 2011)

The Well to Tank (WTT) evaluation accounts for the *energy expended and the associated GHG emitted in the steps required to deliver the finished fuel into the on-board tank of a vehicle*. It also considers the potential availability of the fuels, through their individual pathways and associated costs.

The Tank to Wheels (TTW) evaluation accounts for the *energy expended and the associated GHG emitted by the vehicle/fuel combinations*. It also includes an assessment of the expected relative retail prices of the various vehicle configurations.

We refer to the Well to Wheels (WTW) integration, giving a global assessment of the energy required and the GHG emitted per km driven on the fuel/vehicle combinations considered.

$$WTW \left[\frac{MJ_t}{km}\right] = WTT \left[\frac{MJ_t}{MJ_f}\right] \cdot TTW \left[\frac{MJ_f}{km}\right]$$

example

WTT of most common and promising fuels (EU)

in collaboration with Dept. of Energy (prof. Santarelli), Politecnico di Torino - I

FUEL	WTT [MJ_t/MJ_f]
Fuel-gasoline (petrol)	1.14
Gasoil-diesel	1.16[1]
CNG	1.19
Hydrogen from NG	1.82
Hydrogen from electrolysis (from wind power)	1.74
Hydrogen from electrolysis (European mix)	4.58
Electricity (European mix)	2.86
Electricity (European mix based on carbon)	2.59
Electricity from wind power	0.04
Electricity from nuclear energy	3.73

[1] Nearly *1 barrel each 6* cannot be benefited in its final use.

Source: DALLA CHIARA B., RICAGNO R, SANTARELLI M. (2008). «Sostenibilità energetica dei trasporti: analisi dei consumi e della soluzione ferroviaria». INGEGNERIA FERROVIARIA/RAILWAY ENGINEERING. vol. LXIII, pp. 531-543, ISSN: 0020-0956. N. 6, 2008.

TTW, motor-cars (EU)

PROPULSIVE TECHNOLOGY	TTW [MJ_f/km]
ICE, **fuel/gasoline/petrol***	**1.91**
ICE – **gasoil/diesel***	1.72
ICE –**CNG**	1.9
ICE –**Hydrogen**	1.67
ICE, **hybrid- fuel/gasoline**	1.62
ICE- **hybrid –gasoil/diesel**	1.41
Electric car with, batteries	1.1
FC – **Hydrogen**	0.91

TTW of main propulsive technologies in the motor-car field in 2010

* In 2002, the TTW of ICEs (*internal combustion engines*) – fuel/petrol and gasoil were respectively 2.25 and 2.09 MJ_f/km

TTW, trains (EU)

Full load

TRAIN	TTW $[MJ_f/(t \cdot km)]$	[t/place]*	$[t/place]_{FL}$	Use level	TTW* $[MJ_f/(p \cdot km)]$	TTW_{FL} $[MJ_f/(p \cdot km)]$
TGV (F)	0.148	0.914	0.966	65%	0.209	0.143
ICE (D)	0.104	1.294	1.336	51%	0.263	0.138
AVE (SP)	0.136	1.305	1.346	66%	0.268	0.183

TTW e TTW_{PC} for some European trains*

$$TTW^* \left[\frac{MJ}{pkm}\right] = TTW \left[\frac{MJ}{tkm}\right] \cdot \left[\frac{t}{place}\right] \cdot \left[\frac{p}{place}\right]^{-1}$$

Empirical methods for calcutating the TTW in railways

$$\left[\frac{MJ}{tkm}\right]_{average} = \frac{1}{N}\sum_{i=1}^{N}\left[\frac{MJ}{tkm}\left(v_{aver.};d\right)\right]_i$$

$$\left[\frac{MJ}{tkm}\right] = A \cdot \frac{v^2_{average}}{\ln(x)} + B$$

TRAIN	A	B
ICE, Germany	0.007	74
TGV, France	0.0097	70
APT, Great Britain	0.012	70
Heavy freight trains (more than 600 tons unloaded)	0.019	63
RC, Sweden	0.015	81

Empirical methods for calcutating the TTW in railways

$$F = A_0 + A_1 v + A_2 v^2 + mg \sin\alpha$$

$$F' = B_0 + B_1 v + B_2 v^2 + g \sin\alpha$$

TRAIN	B_0	B_1	B_2
APT, GB	16.6	36.6 10^{-2}	26 10^{-3}
Oldest UK trains	15.5	29.2 10^{-2}	57.4 10^{-3}
Freigh trains	24.7	0	84.5 10^{-3}
IC3, Denmark– single unit	19.7	0	42.5 10^{-3}
IC3, Denmark – multiple units	19.7	0	24 10^{-3}
ICE, Denmark – Loco BR103	16	0	22.5 10^{-3}

$$E' = \frac{1}{L}\int_0^L \left(a + B_0 + B_1 v + B_2 v^2\right) dl + g\,\frac{\Delta h}{L}$$

$$E' \cong \frac{N_{fer} + 1}{L} \cdot \frac{v_{\max}^2}{2} + B_0 + B_1 \cdot v_{med} + B_2 \cdot v_{med}^2 + g \cdot \frac{\Delta h}{L}$$

WTW for car and WTW_{FL} of trains and cars

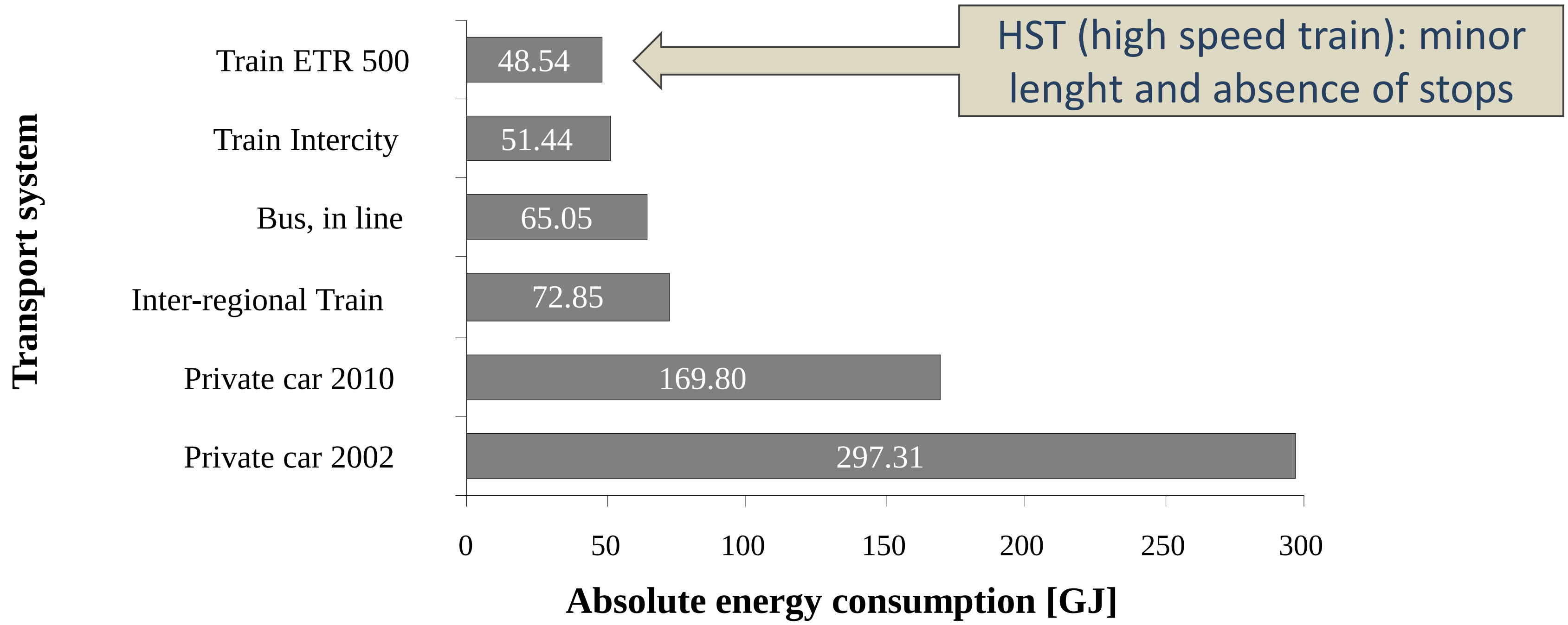
Transport means	WTW [MJ/km]	Case 1 (driver)	Case 2 (average)	Case 3 (5 pass.)
ICE Train –wind power	-		0.005	
TGV Train – wind power	-		0.006	
AVE Train– wind power	-		0.007	
Electric car– wind power	0.044	0.011	0.012	0.013
ICE Train – carbon mix	-		0.333	
ICE Train – EU mix	-		0.368	
TGV Train – carbon mix	-		0.371	
TGV Train – EU mix	-		0.410	
Car FC – H_2 from electrol. from wind power	1.583	0.396	0.440	0.485
Hybrid car – electricty and gasoil	1.636	0.409	0.455	0.501
Car FC – H_2 from Natural gas	1.656	0.414	0.461	0.507
AVE Train – carbon mix	-		0.473	
ICE Train – nuclear energy	-		0.479	
Hybrid car– electrcity and gadsoline/oil	1.847	0.462	0.514	0.565
AVE Train – EU mix	-		0.522	
TGV Train – nuclear energy	-		0.534	
Internal combustion car– gasoli/diesel	1.995	0.499	0.555	0.611
Internal combustion car– oil/gasoline	2.177	0.544	0.605	0.667
Internal combustion car– natutal gas	2.261	0.565	0.629	0.692
AVE Train – nuclear energy	-		0.681	
Electric car– carbon mix	2.849	0.712	0.792	0.872
Internal combustion car– H_2 from electrolysis from wind energy	2.906	0.726	0.808	0.889
Internal combustion car– H_2 from natural gas	3.039	0.760	0.845	0.930
Electric car– EU mix	3.146	0.787	0.875	0.963
Electric car– Nuclear energy	4.103	1.026	1.141	1.256

TTW, WTW e WTW_{FL} for some Italian trains*

TRENO	Primary energy source	Occupancy	TTW [kJ/(t·km)]	TTW* [MJ/(p·km)]	TTW_{FL} [MJ/(p·km)]	WTW* [MJ/(p·km)]	WTW_{FL} [MJ/(p·km)]
IC	EU Mix	> 50%	70.49	0.118	0.062	0.336	0.176
	carbon. Eur. Mix					0.304	0.159
	Wind energy					0.005	0.002
IR	EU Mix	> 50%	109.4	0.187	0.098	0.476	0.280
	carbon. Eur. Mix					0.431	0.254
	Wind energy					0.007	0.004
ETR 500	EU Mix	54.8%	74.35	0.136	0.077	0.388	0.220
	carbon. Eur. Mix					0.352	0.200
	Wind energy					0.005	0.003

example

Example:
Absolute energy consumption on the Turin –Milan link
(by rail, road by private car or PT)



The EU Parliament has launched extensive measures to enhance energy efficiency and energy saving and for the integration of climate change objectives into transport and energy policies as well as the need for specific measures in the transport sector to address energy use and greenhouse gas emissions.

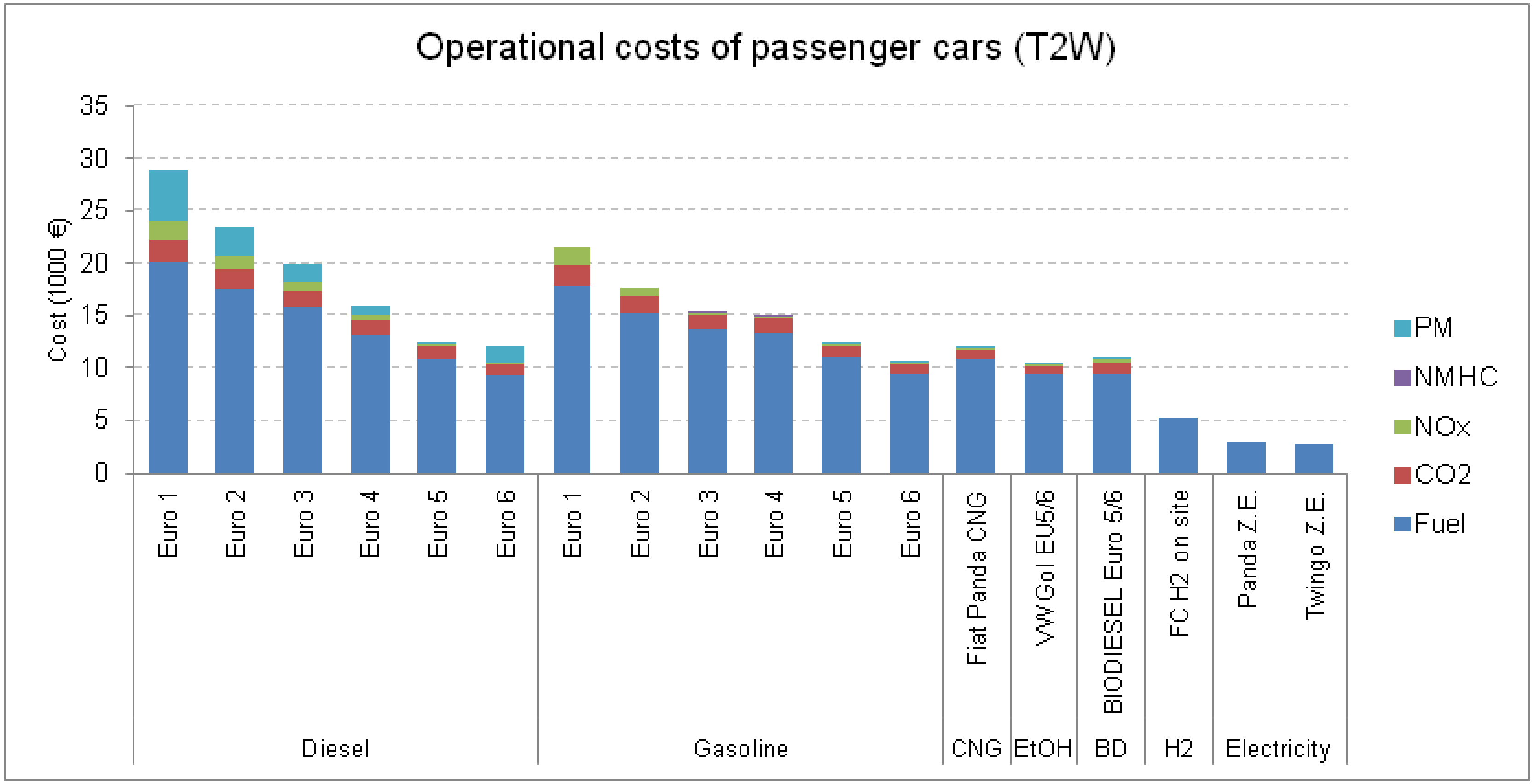
In order to introduce a new culture for urban mobility, the community approved also the support for stakeholders in promoting **more efficient vehicles**.

The approach is based on the **internalisation of external costs** by means of lifetime costs of fuel, CO_2 emissions and pollutant emissions of the vehicles.

Directive 2009/33/EC of the European Parliament and of the Council on the promotion of clean and energy-efficient road transport vehicles

According to requirements of Directive 33/2009, it is possible to obtain details of the various vehicle categories and sub-categories.

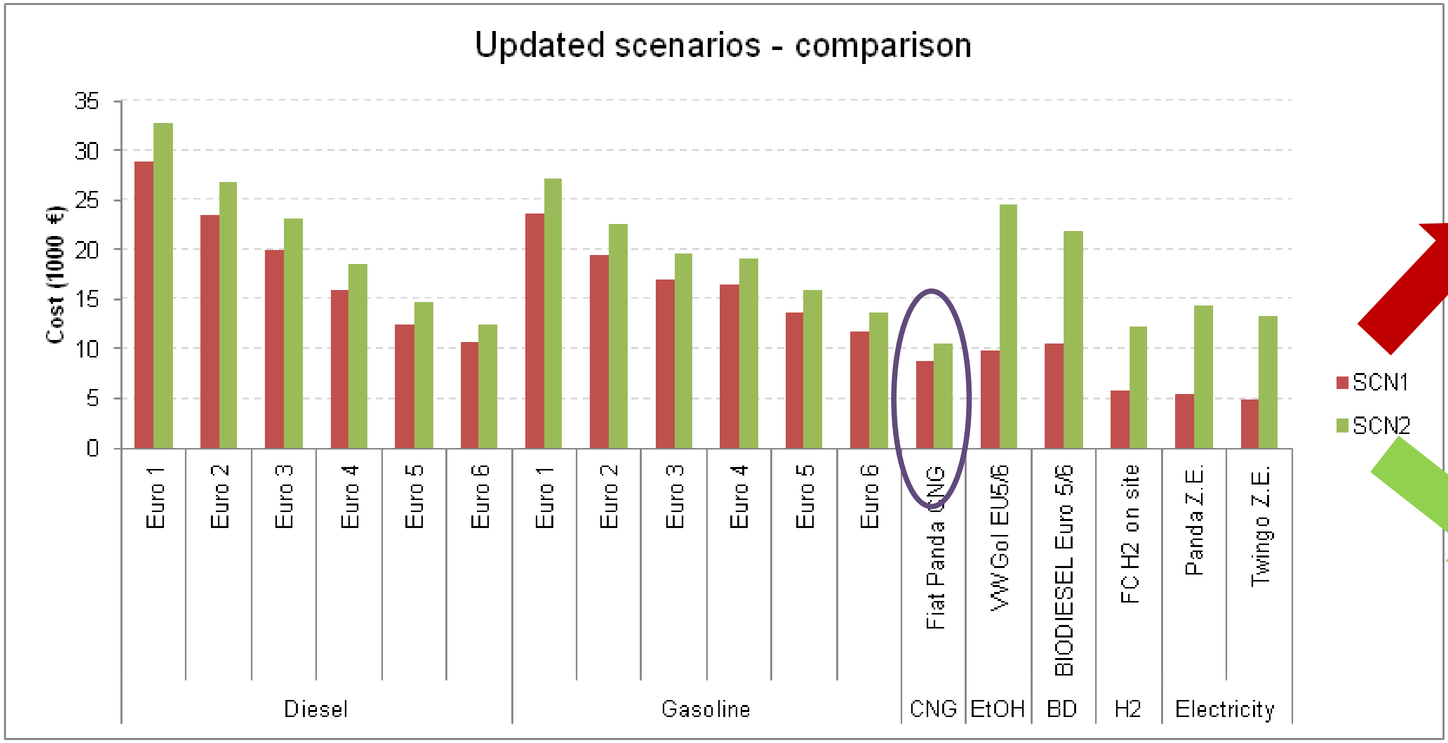
Results for passenger cars <u>only</u> on the base of a $\boxed{\text{TTW analysis,}}$ in I semester 2011 (costs of NG and Diesel/Fuel vary)



Source: Santarelli, De Oliveira – Politecnico di Torino, I Semester, 2011

- *Particulate matter*
- *Non methanique hydrocarbures*
- *Nytrogen oxides*

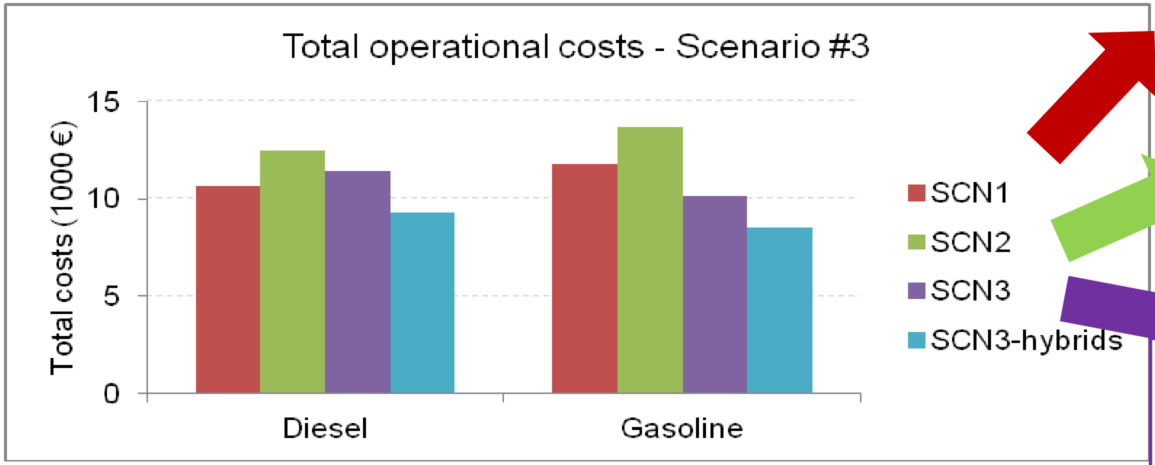
Scenarios	Description of SCENARIOS for TTW and WTW
SCN1	Cost based on the internalization of external costs by means of lifetime costs of fuel, CO_2 emissions and pollutant emissions of the vehicles (TTW) → previous graph
SCN2	It considers the **well to wheel** analysis of the electricity and also of all others energy carriers or vectors (WTW)
SCN3	Inclusion of analysis of a short term forecast, in which **new technologies** under development are taken into account and compared with previous scenarios (WTW)
SCN4	Inclusion of analysis of a **long term forecast**, in which new technologies and fuels will become affordable and applicable in large scale (WTW)



Source: Dalla Chiara, Pinna, Navarro Herdy – Politecnico di Torino, November 2011

Cost based on the internalization of external costs by means of lifetime costs of fuel, CO2 emissions and pollutant emissions of the vehicles **(T2W)**

It considers the **well to wheel (W2W)** analysis of the electricity and also of all others energy vectors



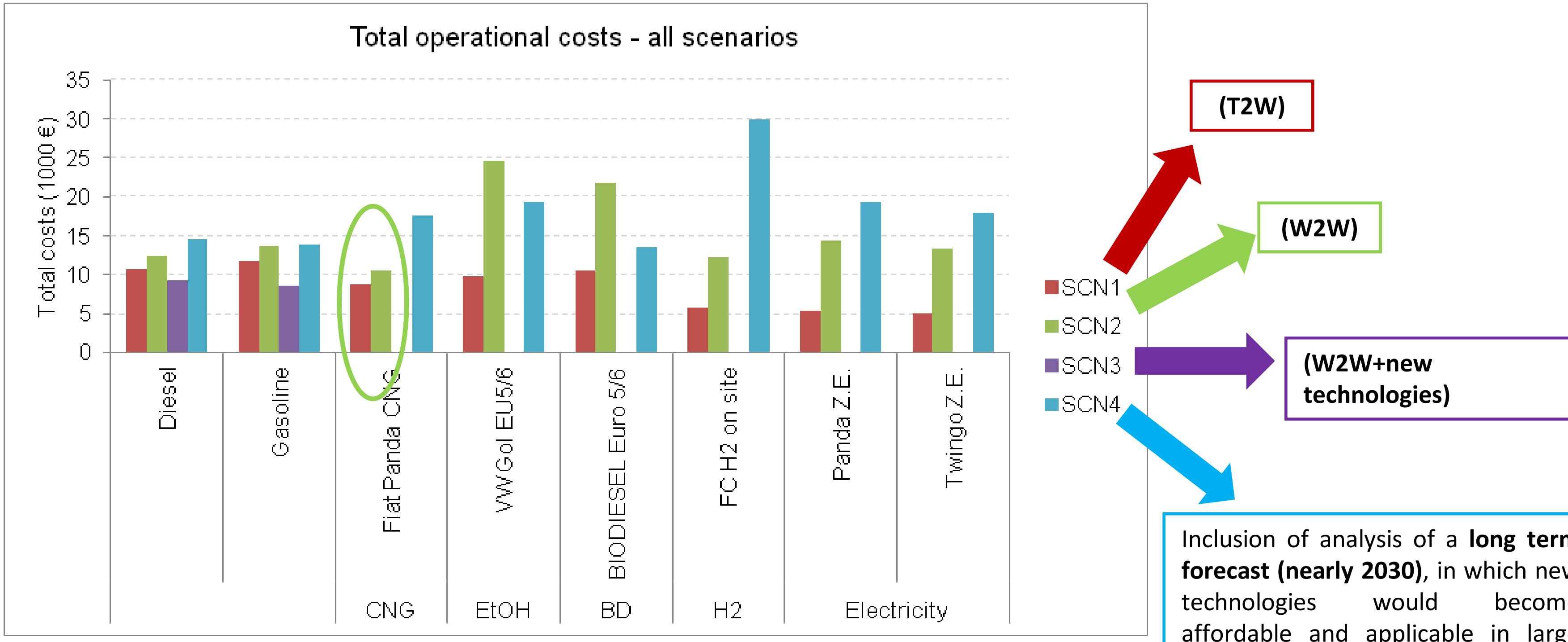
(T2W)

(W2W)

Source: Dalla Chiara, Pinna, Navarro Herdy – Politecnico di Torino, November 2011

Inclusion of analysis of a short term forecast, in which **new technologies (turbocharging/downsizing, variable valve actuation**) under development are taken into account and compared with previous scenarios **(W2W+new technologies); estimations!**

Hypotheses on the future on the base of the present situation (in Europe, the CNG network has been already paied)

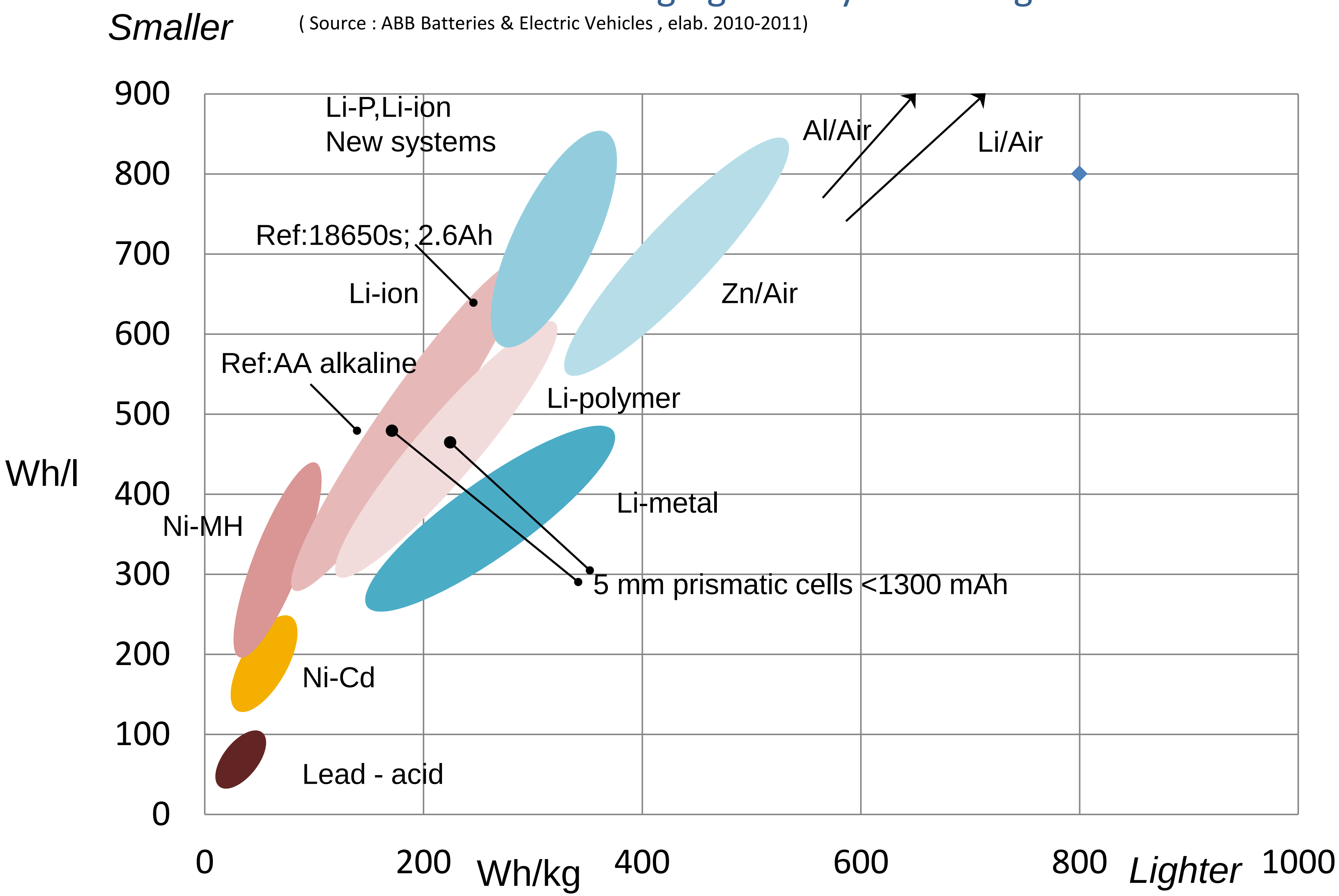


Inclusion of analysis of a **long term forecast (nearly 2030)**, in which new technologies would become affordable and applicable in large scale **(W2W)**

Source: Dalla Chiara, Pinna, Navarro Herdy – Politecnico di Torino, November 2011

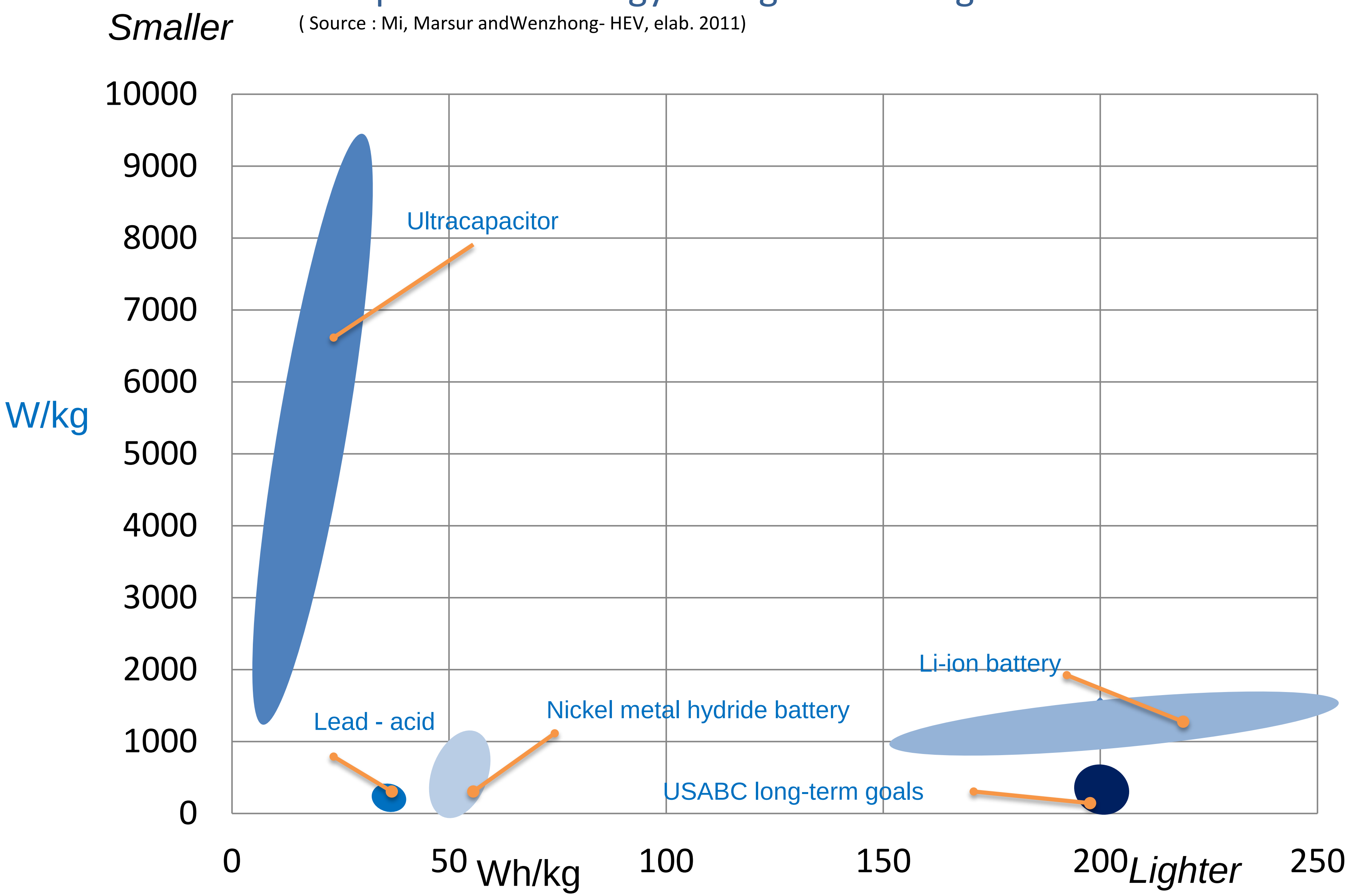
Established and emerging battery technologies

(Source : ABB Batteries & Electric Vehicles , elab. 2010-2011)

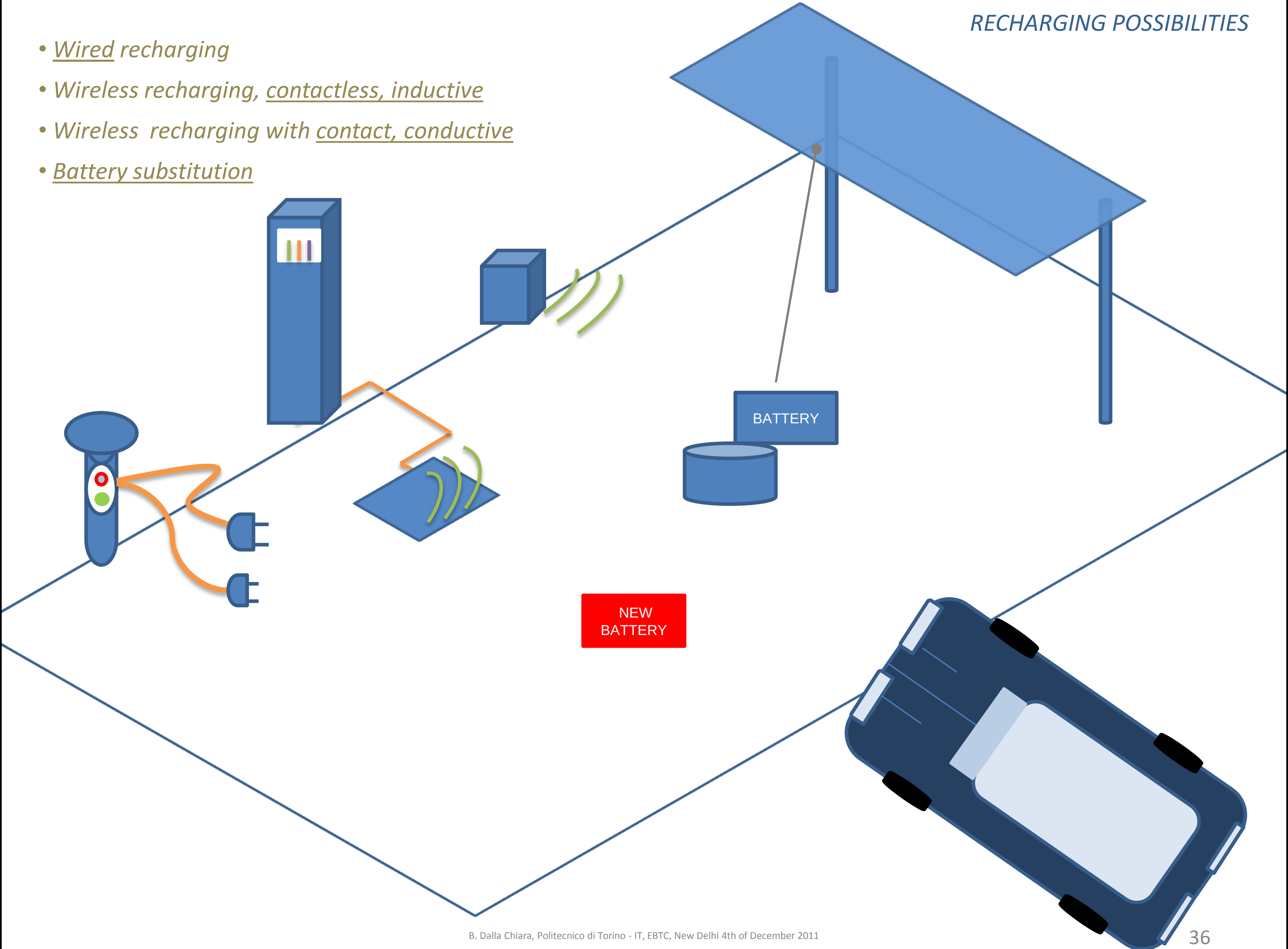


Comparison of energy storage technologies suitable for HEVs

(Source : Mi, Marsur andWenzhong- HEV, elab. 2011)



- *Wired recharging*
- *Wireless recharging, contactless, inductive*
- *Wireless recharging with contact, conductive*
- *Battery substitution*



Most important European Communications, Action Plans and legislation concerning urban ITS deployment and Energy issues include :

- The ITS Directive (2010/40/EU)

concerned with the coordinated and coherent deployment of ITS within the Union including the development of specifications and standards.

- Action Plan on Urban Mobility (COM (2009) 490)

on sustainable urban mobility and concerned with ITS deployment in urban areas in regard to "Action 20: ITS for urban mobility" (e.g., electronic ticketing and payment, traffic management, travel information, access regulation and demand management and opportunities via Galileo).

- Action Plan for the Deployment of ITS in Europe (COM (2008) 886)

adopted to accelerate and coordinate the deployment of ITS is especially concerned with urban ITS in regard to "Action 6.4: Set up of a European Urban ITS collaboration platform on urban mobility". As a result of this action the "Urban ITS Expert Group" has been established by the European Commission with key stakeholders and organisations.

[Source: elaboration from ERTICO thematic paper: "ITS for Urban Mobility", Nov 2011]

- **White Paper "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system"** (COM (2011) 144):

Published in 2011, concerned with competitive and resource efficient European transport systems which includes inter alia "clean urban transport and commuting". Use of "conventionally fuelled" cars in urban transport should be halved by 2030 and they should be phased out in 2050. Furthermore, major urban logistics should be CO2 free by 2030. In addition goals 8 (the establishment of the framework for European multimodal transport information, management and payment system by 2020) and 9 (close to zero road fatalities on road transport by 2050) are concerned with urban mobility.

- **Green Paper "Towards a new culture for urban mobility"** (COM (2007) 551):

In the Green Paper on urban mobility the deployment of ITS in urban areas is clearly emphasised in section 2.3 "Towards smarter urban transport".

- **Digital Agenda for Europe**

Action 92: Apply the Intelligent Transport System Directive in support of interoperability and rapid standardisation.

- **A European strategy on clean and energy efficient vehicles** (COM (2010) 186):

According to this communication fully electric vehicles (FEV) are said to be most promising especially in urban use.

[Source: elaboration from ERTICO thematic paper: "ITS for Urban Mobility", Nov 2011]

- Directive 2009/33/EC of the European Parliament and of the Council on the promotion of clean and energy-efficient road transport vehicles.

  - Aims to stimulate the market for clean and energy-efficient road transport, and especially – since this would have a substantial environmental impact – to influence the market for standardized vehicles produced in larger quantities: passenger cars, buses, coaches and trucks;
  - the aim is to ensure a level of demand for clean and energy-efficient road transport vehicles which is sufficiently substantial to encourage manufacturers and the industry to invest in and further develop vehicles with low energy consumption, CO_2 emissions, and pollutant emissions.

- "A sustainable future for transport", European Parliament resolution of 6 July 2010 on a sustainable future for transport (2009/2096(INI))
  2 December 2011

- "Intelligent Transport Systems in the field of road transport and interfaces with other transport modes"
  European Parliament legislative resolution of 6 July 2010 on the Council position at first reading with a view to the adoption of a directive of the European Parliament and of the Council on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport (06103/4/2010 – C7-0119/2010 – 2008/0263(COD)),
  2 December 2011

Conclusions

Towards:

OIL-INDEPENDENT ROAD TRANSPORT

ITS

RAILWAYS, APMs, METROS, systems in fixed guideways, including rope traction

Some EU cities, today

FUTURE **AIMS** OF SOCIETY

QUALITY,
SAFETY,
SECURITY,
EFFICENCY

Technological solutions

Automated People movers and Metros

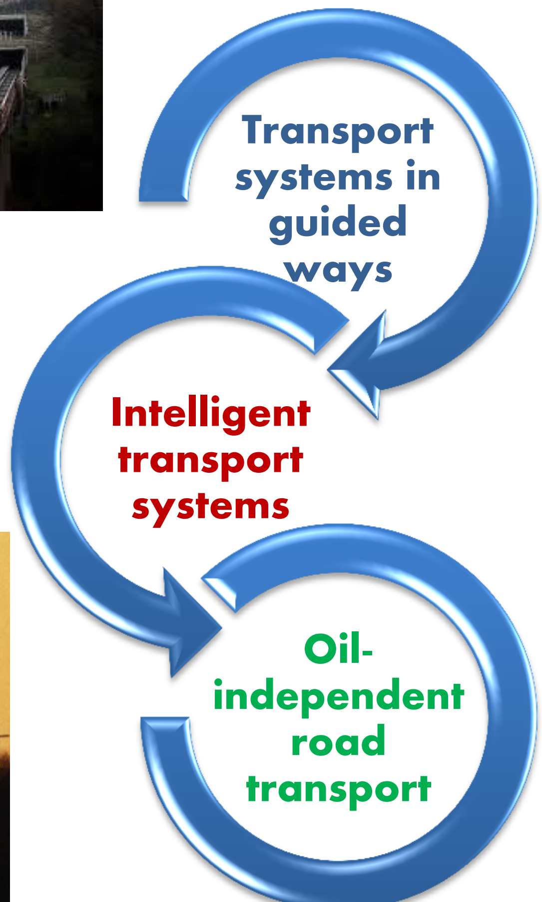
Intelligent transport systems

More oil-independent vehicles and green motor vehicles

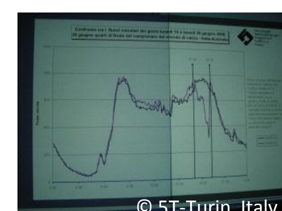
including bike sharing

Some EU trends in cities

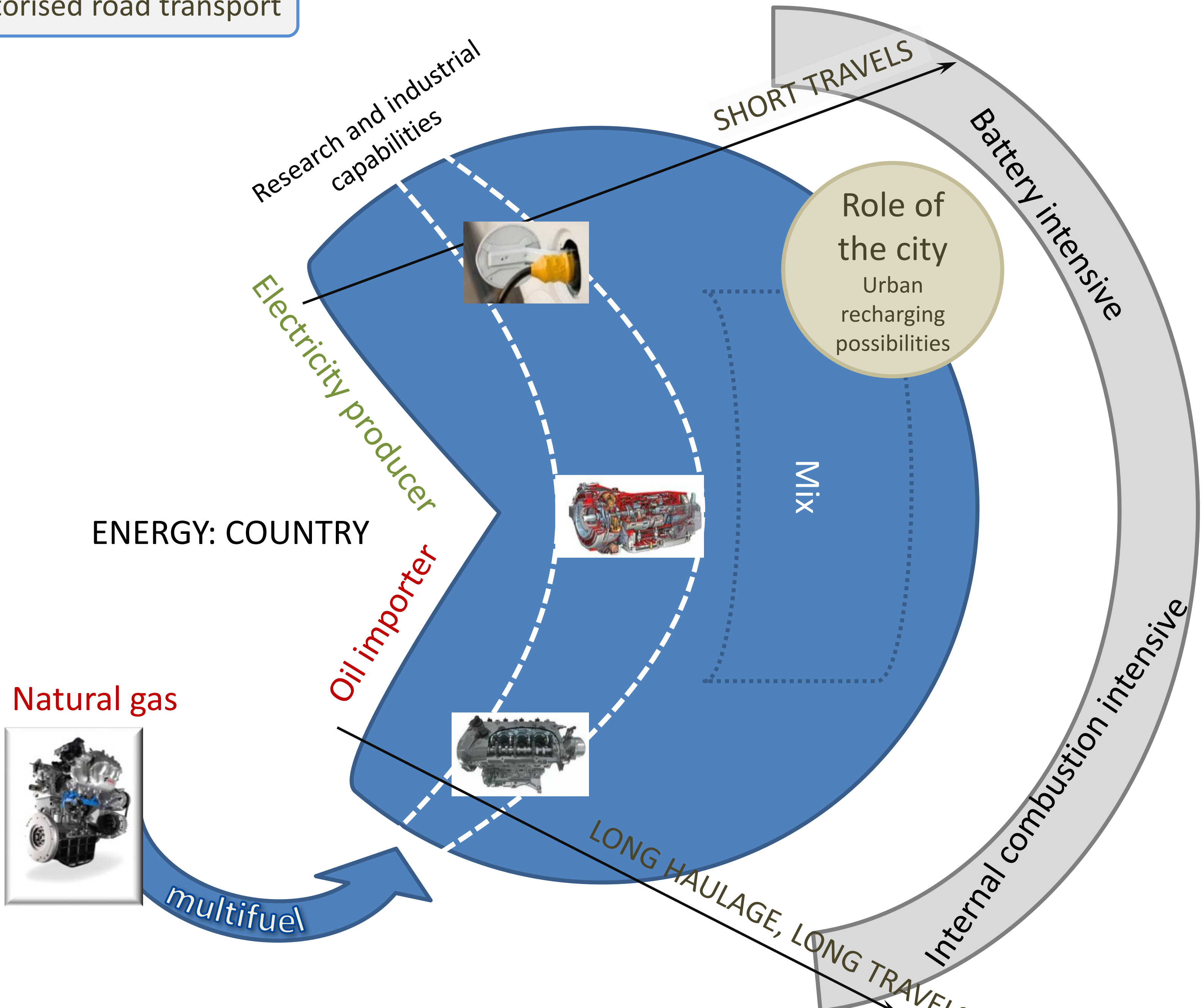




Motorised road transport



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